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Wetlands Research Program Technical Report WRP-SM-4

Selective Control of Purple Loosestrife with Triclopyr

by Linda S. Nelson, Kurt D. Getsinger, Jan E. Freedman



June 1995 – Final Report

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	Task		Task
CP	Critical Processes	RE	Restoration & Establishment
DE	Delineation & Evaluation	SM	Stewardship & Management

Wetlands Research Program

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U.S. Army Corps of Engineers
Waterways Experiment Station
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Final report

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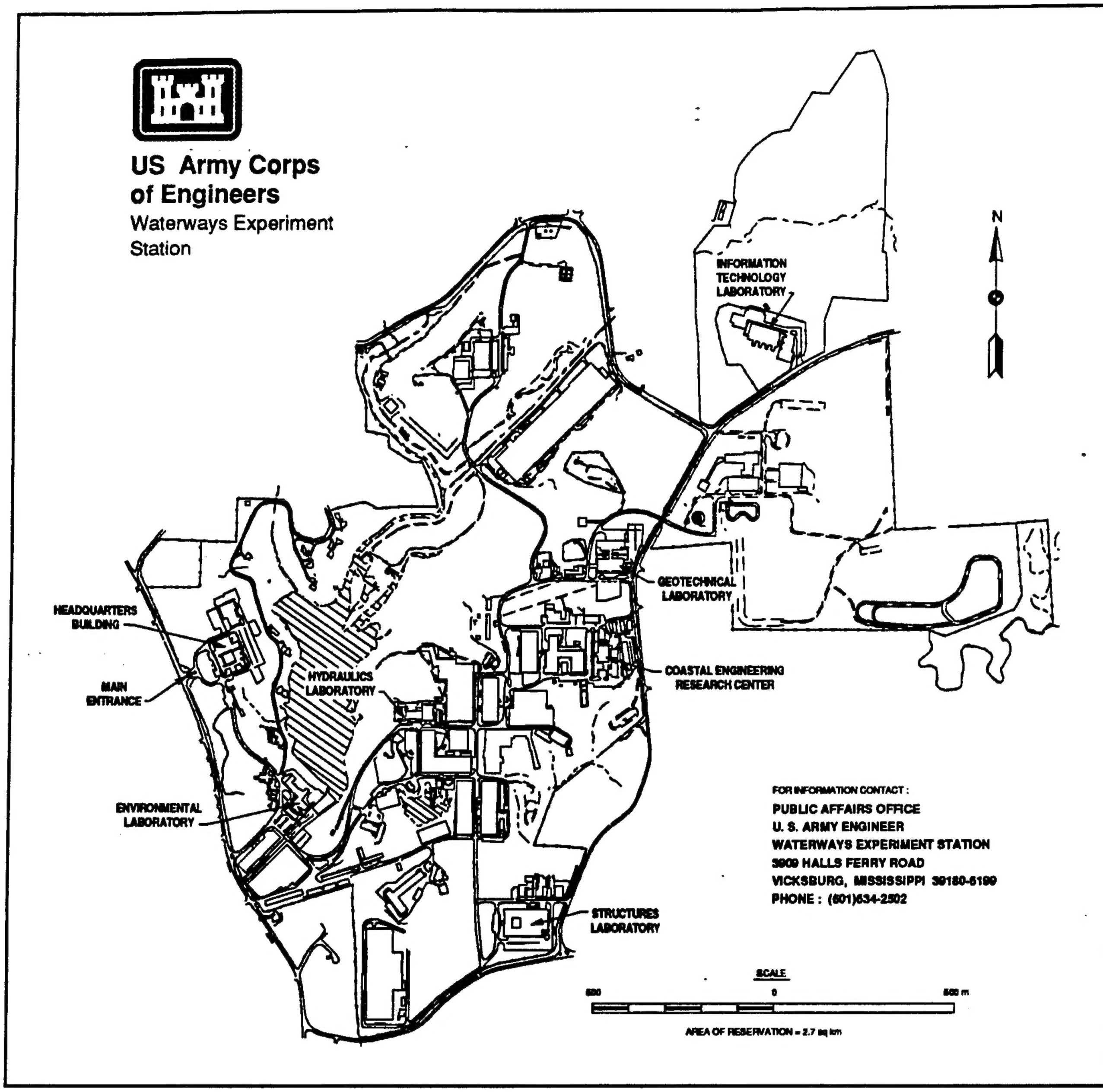

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Corps of Engineers Research Report Summary, June 1995

Wetland Pests

Selective Control of Purple Loosestrife with Triclopyr (TR WRP-SM-4)

ISSUE:

Purple loosestrife is an invasive plant that threatens biodiversity of natural wetlands in more than 40 states. This exotic species can displace native vegetation through rapid growth and heavy seed production, resulting in monotypic stands that dramatically reduce vegetative diversity, while providing little food or habitat for associated wildlife. Purple loosestrife can establish and thrive in areas where natural and man-made disturbances (including vegetation management techniques) eliminate native wetland plant communities.

Use of conventional, nonchemical management techniques, e.g., flooding, draining, cutting, and burning, is inherently nonselective and seldom results in long-term control of purple loosestrife infestations. Approved herbicides offer a selective technique for reducing purple loosestrife levels, eradicating pioneer colonies of the plant and restoring native wetland communities.

RESEARCH:

Primary objectives were to evaluate effectiveness of triclopyr on purple loosestrife, and to monitor changes in wetland plant community following triclopyr treatment.

The research resulted in a technique for controlling purple loosestrife in wetland communities using a herbicide that includes minimizing damage to nontarget plants, particularly monocots, while offering a potential for restoring a diverse plant community.

SUMMARY:

Results from this work will be used to provide initial guidance for the selective control of purple loosestrife using triclopyr. Data will be used to support the national aquatic registration of that herbicide.

AVAILABILITY OF REPORT:

The report is available on Interlibrary Loan Service from the U.S. Army Engineer Waterways Experiment Station (WES) Library, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, telephone (601) 634-2355.

To purchase a copy, call the National Technical Information Service (NTIS) at (703) 487-4650. For help in identifying a title for sale, call (703) 487-4780. NTIS report numbers may also be requested from the WES librarians.

About the Authors:

Linda S. Nelson is a plant physiologist, Dr. Kurt D. Getsinger is a research biologist, and Jan E. Freedman is a biologist at the WES Environmental Laboratory. Point of contact is Ms. Nelson at (601) 634-2656.

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Preface

The work reported herein was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Stewardship and Management Task Area of the Wetlands Research Program (WRP). The work was performed under Work Unit 32766, "Wetland Stewardship and Management Demonstration Areas" for which Dr. Alfred F. Cofrancesco, Jr., was Technical Manager. Ms. Denise White (CECW-ON) was the WRP Technical Monitor for this work.

Mr. Dave Mathis (CERD-C) was the WRP Coordinator at the Directorate of Research and Development, HQUSACE. Dr. William L. Klesch, (CECW-PO) served as the WRP Technical Monitor's Representative; Dr. Russell F. Theriot, U.S. Army Engineer Waterways Experiment Station (WES), was the Wetlands Program Manager, and Mr. Chester Martin, WES, was the Task Area Manager.

This work was performed at WES by Ms. Linda S. Nelson and Dr. Kurt D. Getsinger, Ecosystem Processes and Effects Branch (EPEB), Environmental Laboratory (EL), and Ms. Jan E. Freedman, Aquatic Ecology Branch (AEB), EL. This investigation was conducted under the general supervision of Dr. Richard E. Price, Acting Chief, EPEB; Mr. Donald L. Robey, Chief, Environmental Processes and Effects Division; Mr. Carl E. Brown, Chief, Wetlands Branch; Dr. Conrad J. Kirby, Chief, Ecological Research Division; and Dr. John W. Keeley, Director, EL.

Technical reviews of this report were provided by Dr. Cofrancesco, AEB, and Dr. Susan Sprecher, EPEB. Technical assistance was provided by Mr. Richard Otto, Mr. Randy Urich, Mr. Dan Oles, Mr. Eric Roers, Mr. Jerry Lee, and Mr. Loren Danson, U.S. Army Engineer District, St. Paul, Mississippi River Project Office, LaCrescent, MN; Mr. Tony Batya and Mr. Bob Drieslein, U.S. Fish and Wildlife Service, Winona District; and Mr. Jason Eakin, WES. The cooperation of DowElanco for providing herbicide for the study and the technical advice of Dr. Michael P. Stafford, Snake River Chemical (formerly of DowElanco), were greatly appreciated.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. COL Bruce K. Howard, EN, was Commander.

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Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acres	4,046.873	square meters
feet	0.3048	meters
pints (U.S. liquid)	0.4731765	liters

1 Introduction

Purple loosestrife (*Lythrum salicaria*), an emergent, herbaceous perennial of Eurasian origin, was first reported along the northeastern coast of North America in the early 1800s. Since then, this highly invasive wetland plant has spread to 40 States and Canada, with serious infestations extending to the Pacific Northwest and populations reported as far south as Huntsville, AL, and Beaumont, TX. Once established in a wetland, purple loosestrife displaces native vegetation through rapid growth and prolific seed production. A single mature plant can produce more than 2.5 million seeds per growing season (Thompson, Stucky, and Thompson 1987). This large seedbank is highly viable with a germination rate of >95 percent for fresh seed and 80 percent after 2 to 3 years' submergence (Shamsi and Whitehead 1974). The end result is a monotypic stand of purple loosestrife that not only dramatically decreases the vegetative diversity of the wetland but also provides little food or habitat for associated wildlife (Smith 1964; Rawinski and Malecki 1984; Thompson, Stucky, Thompson 1987). Several states (California, Idaho, Washington, Minnesota, Ohio, and Wisconsin) and one Canadian Province (Manitoba) currently have legislation to combat the spread of this exotic plant pest.

Management techniques including flooding, draining, handpulling, burning, cutting, and herbicide applications, have been evaluated against purple loosestrife with varying degrees of success. Use of these methods seldom results in long-term control. Furthermore, their implementation can be too destructive for areas with specific management objectives, e.g., maintenance of wildlife habitat or community diversity. Several researchers also report that physically disturbing an area is an open invitation for purple loosestrife invasion (Thompson, Stucky, and Thompson 1984; Welling and Becker 1992). The need to maintain wetland community integrity requires use or development of minimum impact management strategies. Although it is not practical to assume that purple loosestrife will ever be eradicated from wetlands in the United States, new chemical and biological control strategies currently under investigation look promising.

Review of Chemical Technology

Herbicides currently used to manage purple loosestrife include the following: glyphosate (*N*-(phosphonomethyl)glycine), 2,4-D ((2,4-dichlorophenoxy)acetic acid), and triclopyr ([(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid). Of these compounds, glyphosate and 2,4-D are fully registered by the U.S. Environmental Protection Agency (EPA) for use in aquatic and wetland areas. Triclopyr is under review for aquatic registration and is used on a site-by-site basis under an Experimental Use Permit (EUP) granted by the EPA in 1986. Recently, the state of Minnesota was given approval by the EPA to use triclopyr on 2,000 acres[1] of purple loosestrife under a Section 18, Emergency Exemption. Triclopyr is also being used under a similar label exemption on 400,000 to 800,000 acres of rice in the southeastern United States for broadleaf weed control. Final data submission to the EPA for full aquatic registration of triclopyr is expected in 1996.

Glyphosate

Glyphosate is a broadspectrum herbicide used extensively in crop, noncrop, and aquatic environments. Glyphosate is nonselective and very effective on deep-rooted perennial species and on annual and biennial species of grasses, sedges, and broadleaf weeds. Uptake is through the foliage, and translocation occurs readily throughout the plant. The mode of action of glyphosate is via the shikimic acid pathway where inhibition of 5-enolpyruvylshikimate-3-phosphate synthase (EPSP) prevents the biosynthesis of aromatic amino acids, which are essential for production of proteins (Weed Science Society of America (WSSA) 1989). Depending on the plant species, visible symptoms of injury (wilting and leaf chlorosis) can occur within 2 to 4 days; however, activity in terms of plant death is slow, usually requiring 7 to 14 days.

The environmental and toxicological characteristics of glyphosate are well-known. Outside plant tissues, glyphosate has little activity. Once intercepted by the soil, it is rapidly inactivated because of its ability to strongly adsorb to soil particles. As a result, there is very little soil leaching off the target site of application. Glyphosate is biodegraded both aerobically and anaerobically by microorganisms in soil, water, and sediment. The average soil half-life is less than 60 days, and 90 percent of applied glyphosate is degraded within 6 months (WSSA 1989). In aquatic situations, a minimum half-life of 2 weeks has been observed; however, in static, natural water systems, longer half-lives (7-10 weeks) have been reported (Westerdahl and Getsinger 1988). Tooby (1985) concluded that glyphosate residues decline fairly rapidly in natural waters because of adsorption onto particulate matter. In addition, glyphosate is of low toxicity to birds, mammals, aquatic invertebrates, and fish. Toxicological properties of glyphosate are summarized in Appendix A.

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[1] A table of factors for converting non–SI units of measurement to SI units is presented on page vi.

There are several glyphosate formulations available for use depending on the area receiving the application. In aquatic and wetland environments, the isopropylamine salt formulation, marketed under the trade name Rodeo, should be used. The only difference between the aquatic formulation and those used in agricultural situations (e.g., Roundup) is that Rodeo does not contain a premixed surfactant. The recommended label rate of application for control of purple loosestrife is 4 pints of Rodeo per acre as a broadcast spray or as a 1.0- to 1.5-percent solution if spot spraying small infestations using hand-held equipment. Addition of a non-ionic surfactant approved for aquatic applications (e.g., X-77 Spreader or Cide-Kick) to the tank mixture is advised to maximize spray coverage and chemical penetration of leaf surfaces. Several researchers showed greater than 90-percent reduction of purple loosestrife shoots following treatment with glyphosate (Balogh 1986; Riego 1985; Malecki and Rawinski 1985).

Timing of application is important to achieve adequate chemical efficacy. Studies by Malecki and Rawinski (1985) showed no significant difference in three application rates of glyphosate (1.7, 3.4, and 6.7 kg ha^{-1}) but a highly significant difference in the date of applications. Glyphosate applied during late flowering (August) was more effective than applications made during either the vegetative (June) or early-flowering (July) growth stage. At late flowering, carbohydrate reserves in underground storage organs are at their lowest, and plants are actively photosynthesizing to meet the demands of reproduction. Malecki and Rawinski (1985) also found that timing of application affected the degree of purple loosestrife reinfestation in the treatment area. Plots sprayed in June became reinfested with purple loosestrife seedlings 1 year after application, whereas plots sprayed in July and August were free of seedlings. Welling and Becker (1992) caution however, that any reduction in the number of established purple loosestrife plants in a wetland, whether by artificial manipulation (herbicide or mechanical) or natural factors, is often short-lived because of recruitment from the seedbank.

Although glyphosate is effective against purple loosestrife, one disadvantage with the use of this compound is that it is nonselective. Broadcast spraying a nonselective herbicide kills most of the vegetation in the area of treatment. Using a nonselective herbicide is appropriate for "spot" applications to remove small infestations; however, it may not be the treatment of choice in situations where purple loosestrife is well established and where a large seedbank exists. The lack of chemical selectivity, coupled with the invasive nature of purple loosestrife and its highly viable seedbank, only increases the accessibility of the treated area to seedling recruitment. If glyphosate is used, follow-up treatments are recommended to remove plants that survived the first application. Reseeding a desirable plant species (replacement control), such as Japanese millet (*Echinochloa crusgalli* var. *frumentacea*), on glyphosate-treated areas to compete with germinating loosestrife seedlings has also been investigated, but has limited application because

of cost and area accessibility (Balogh 1986; Malecki and Rawinski 1985; Rendall 1987;[1] Thompson, Stucky, and Thompson 1987).

2,4-D

2,4-D is a systemic herbicide that is widely used for control of broadleaf (dicotyledons) weeds in cereal crops, sugarcane, turf, pastures, and various noncrop areas including aquatic environments. Plants absorb 2,4-D through their leaves and roots within 4 to 6 hr after application. Following absorption, 2,4-D is translocated throughout the plant in the phloem and accumulates in meristematic regions of shoots and roots where it causes profound effects on growth and structure. Although the mode of action of 2,4-D has not been clearly established, treatment causes parenchyma cells to divide, producing callus tissue and expanding root primordia, excessive vascular tissue formation in young leaves, and root growth inhibition.[2] 2,4-D-induced tissue proliferation leads to symptoms of stem and leaf epinasty (downward bending or curling) and stem and root tip swelling. This abnormal growth stimulation causes plant death in several days or weeks. Plant metabolism is also affected by 2,4-D through modification of enzyme activity, respiration, nucleic acid synthesis, protein synthesis, and through obstruction of the phloem, thus interfering with food transport (Munro et al. 1992). Because the effects on plant growth appear to act at the same site as the natural plant auxin, indole-3-acetic acid (IAA), 2,4-D is often referred to as an auxin-type herbicide or growth regulator herbicide.

Unlike glyphosate, 2,4-D is selective, affecting mainly dicotyledonous plants. The difference in response between monocots and dicots is partially due to their differences in vascularization. Monocots have scattered vascular bundles surrounded by protective schlerenchyma cells that may prevent destruction of the phloem by 2,4-D.[2] The advantage of chemical selectivity is control of the target, dicot plant species (i.e., purple loosestrife) with minimal disturbance to most nontarget, monocot plant species.

2,4-D and its derivatives are rapidly degraded through hydrolysis, photolysis, and especially by microbial activity (Westerdahl and Getsinger 1988; WSSA 1989). Rate of biological degradation depends on temperature, moisture, organic matter, and other soil/sediment characteristics that affect microbial activity. The resultant average persistence of phytotoxicity in soil at recommended treatment rates is 1 to 4 weeks in a warm, moist soil (WSSA 1989). 2,4-D acid has a low persistence in water, with a half-life less than 2 weeks (Westerdahl and Getsinger 1988). All growth regulator herbicides

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[1] Unpublished Report, Rendall, J. (1987). "Element stewardship abstract for *Lythrum salicaria*, purple loosestrife," The Nature Conservancy, Midwest Regional Office, Minneapolis, MN.

[2] Liebl, R. (1993). Course Notes, "Growth regulator herbicides," Herbicide Action Course, Purdue University.

have low mammalian toxicity. The toxicological properties of 2,4-D are summarized in Appendix A.

Both the isooctyl ester (SEE 2,4-D, WEED RHAP LV-4D) and the dimethylamine salt (WEEDAR 64, WEED RHAP A-6D) formulations of 2,4-D are currently registered by EPA for aquatic use and can be used to control purple loosestrife. However, following the imminent herbicide re-registration process required by EPA, some of these 2,4-D formulations may no longer maintain aquatic use labels. Of these formulations, esters are usually more phytotoxic and also potentially more toxic to fish than amine salts and may be a consideration in product selection. Refer to product labeling information in Appendix A for recommended use rates and use restrictions for each formulation. Addition of a surfactant approved for aquatic use should be added to the spray mixture to maximize coverage and leaf penetration. Purple loosestrife should be treated when plants are young and actively growing and near the bud stage but not flowering (late May to early June). Higher rates are recommended when plants are mature and weed mass is dense. Welling and Becker (1992) reported that application of 2,4-D to outdoor flats of seedling communities reduced purple loosestrife frequency and population density by 44 and 94 percent, respectively. In contrast, 2,4-D treatments were only 50 percent effective when sprayed on older, blooming loosestrife plants (Notestein 1985). Consequently, timing of application is critical to maximize chemical efficacy. The only disadvantage of treating early in the season is that purple loosestrife plants are easily overlooked when not in flower. Repeat applications in subsequent years may also be necessary.

Triclopyr

Triclopyr is an auxin-type, systemic herbicide used for selective, post-emergent control of many woody and herbaceous broadleaf plants in industrial, forestry, and noncrop sites. Triclopyr's mode of action, uptake and translocation, and spectrum of weed control, is similar to that of phenoxy herbicides such as 2,4-D (WSSA 1989). As previously stated, triclopyr is currently under development for use as an aquatic herbicide. Recent field tests indicate that the triethylamine salt formulation of triclopyr (Garlon 3A) is effective against purple loosestrife, as well as several other nuisance aquatic species including Brazilian pepper (*Schinus terebinthifolius*), Eurasian watermilfoil (*Myriophyllum spicatum*), water hyacinth (*Eichhornia crassipes*), and alligatorweed (*Alternanthera philoxeroides*) (Netherland and Getsinger 1993; Woodburn, Green, and Westerdahl 1993). Furthermore, in regard to the recent controversy over the re-registration of 2,4-D under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (Munro et al. 1992), triclopyr may become an important alternative tool for managing these exotic, aquatic weeds.

Photodegradation is the main mechanism for triclopyr breakdown in aquatic systems. Photodecomposition is rapid, with a half-life of 10 days in water at 25° C (WSSA 1989). Triclopyr will also undergo microbial

degradation in aquatic environments, with an observed half-life of approximately 40 days in a darkened aerobic soil/water system (Woodburn, Green, and Westerdahl 1993). Triclopyr has a low level of toxicity to microbial communities and higher aquatic organisms, and residue accumulation in sediment, shellfish and fish is negligible (Dow Chemical Company 1988; Green et al. 1989; Woodburn, Green, and Westerdahl 1993). The toxicological characteristics of triclopyr are summarized in Appendix A.

As with 2,4-D, the selective properties of triclopyr give this herbicide a distinct advantage over other chemical management strategies. Broadleaf weeds such as purple loosestrife are susceptible to triclopyr, whereas many beneficial aquatic plants (monocots such as cattail (*Typha* sp.) and grasses) are not. Vegetation tolerant to triclopyr remains in place and thus can compete with germinating loosestrife seedlings. This is especially important when managing established purple loosestrife populations, where the presence of an abundant seedbank usually results in rapid reinfestation. Overall, the goals of selective weed management are to reduce the target plant species, maintain desirable vegetation, increase biodiversity, and minimize the dependency of repeat herbicide applications.

Proper timing of application is important with use of triclopyr. For maximum effectiveness, triclopyr should be applied to purple loosestrife from the bud to midflowering stage of growth. Applications prior to the bud stage will not control rootstocks. Treatments applied during late flowering may require higher recommended use rates. Addition of a non-ionic surfactant registered for aquatic use is recommended when using triclopyr on purple loosestrife.

In 1992, the Chemical Control Technology Team at the U.S. Army Engineer Waterways Experiment Station (WES) initiated a field demonstration with triclopyr amine on shoreline populations of purple loosestrife along the upper Mississippi River in Minnesota.

The objectives of this investigation were to evaluate the efficacy of triclopyr on purple loosestrife and the resulting vegetative changes to the wetland plant community.

2 Materials and Methods

The study site is located in Pool 5 of the upper Mississippi River, near Weaver Landing in Wabasha County, Minnesota (Figure 1). This area is also known as Weaver Bottoms and is currently managed by the U.S. Fish and Wildlife Service as part of the Upper Mississippi River National Wildlife and Fish Refuge. According to plant surveys, purple loosestrife was well established in this area by 1989. A spray program using glyphosate (Rodeo) was initiated several years ago by refuge managers to control small infestations; however, large, mature populations were considered impractical to treat in this manner, and thus remained intact. The test site selected for this demonstration had not been sprayed with glyphosate or other herbicides in recent years.

Permanent transects measuring 25 m were established in mature stands of purple loosestrife and were randomly assigned one of the following treatments: 0.75 percent Garlon 3A, 1.0 percent Garlon 3A, or untreated Control. Treatments were replicated three times. To enhance spray coverage, a nonionic surfactant, X-77 Spreader, was added to the Garlon 3A spray mixtures at a rate of 0.5 percent volume to volume. Treatments were applied on June 30, 1992, using an airboat equipped with a high-volume handgun sprayer. Vegetation was sprayed to wet with two passes of the airboat. Swath width extended approximately 6 m along either side of each 25-m transect. At the time of treatment, purple loosestrife was in the late-bud to early-flower stage of development.

Prior to chemical application, percent cover of purple loosestrife was determined along each transect using line-intercept techniques. Quadrat (1.0 by 0.5 m placed at 3-m intervals along the transect) sampling was used to determine percent coverage of all associate plant species and subsequent changes between monocot/dicot populations. Within each quadrat, the percent cover of each plant species was recorded using the following cover class values: 1 to 5, 6 to 25, 26 to 50, 51 to 75, 76 to 95, and 96 to 100 percent. Cover values were recorded as the mean of the cover class value (i.e., 2.5, 15, 37.5, 62.5, 85, 97.5) for analysis. The amount of open space was also recorded (in each quadrat). Subsequent vegetation sampling was scheduled for 10 weeks (9 September 1992) and 1- (June 1993) and 2-years posttreatment (June 1994).

Data were subjected to analysis of variance procedures using SAS (SAS Institute 1982). When significant treatment effects were found, means were

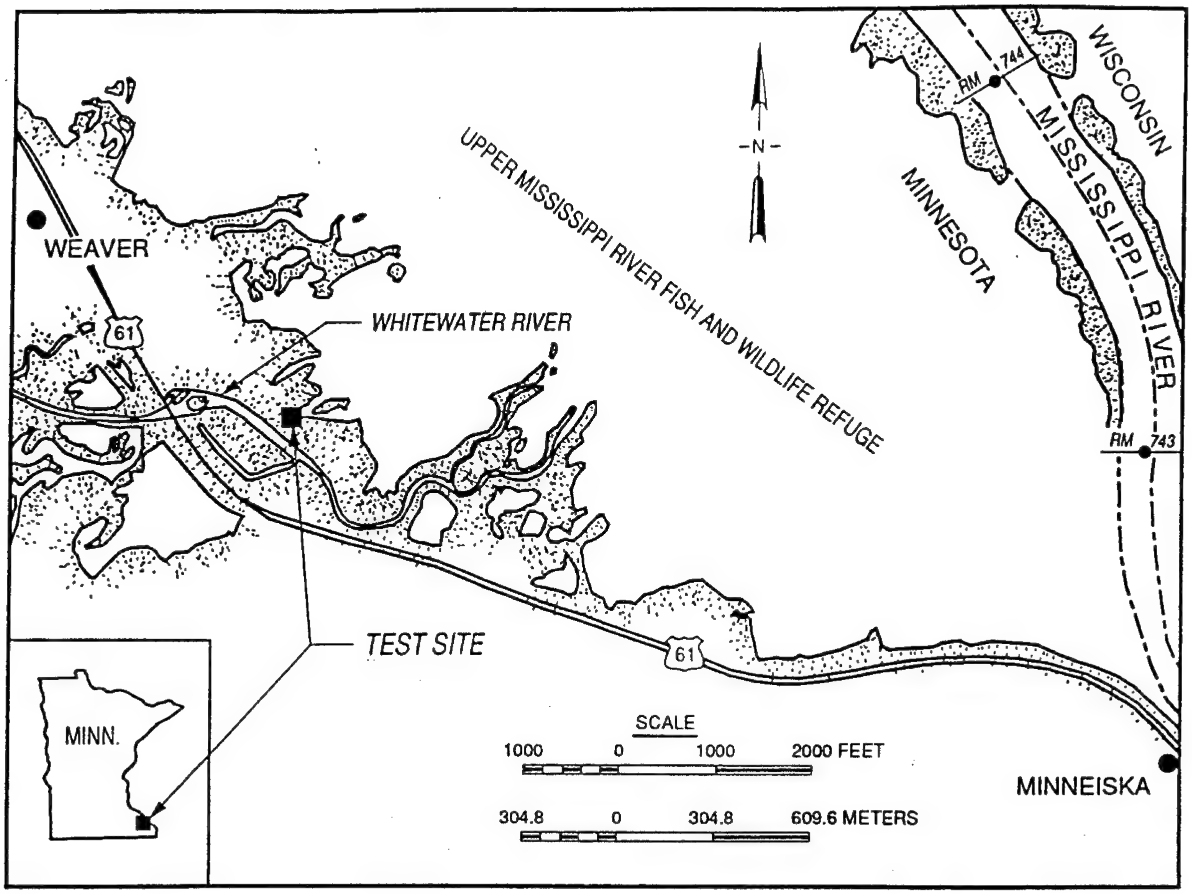

Figure 1. Location of test site in Pool 5 of upper Mississippi River, near Weaver Landing in Wabasha County, Minnesota. Area is also known as Weaver Bottoms and is part of the Upper Mississippi River National Wildlife and Fish Refuge

separated using a protected Least Significant Difference (LSD) test at the 0.05 level of significance.

3 Results and Discussion

Pretreatment vegetation sampling showed that purple loosestrife was the dominant plant species (> 50 percent) in the test area; the most common associate species were broad-leaved arrowhead (*Sagittaria latifolia*) and reed canary grass (*Phalaris arundinacea*) (Table 1). Giant bur-reed (*Sparganium eurycarpum*), duckweed (*Lemna* sp.), spike rush (*Eleocharis* sp.), and broad-leaved cattail (*Typha latifolia*) were frequently encountered species but minor cover components (> 10 percent). Overall, dicots were more abundant in the test area than monocots.

Results showed that triclopyr (Garlon 3A) was an effective treatment for reducing purple loosestrife cover (Table 2). The higher treatment rate (1-percent solution) reduced purple loosestrife by 95 percent 10 weeks after treatment (WAT), while untreated transects showed an increase (28.5 percent) in purple loosestrife cover. There were no significant differences between triclopyr treatment rates. Germinating seedlings (1 to 2 cm tall) were observed in all triclopyr-treated plots at 10 WAT. Seedlings were most abundant in bare-ground areas adjacent to dead loosestrife plants. Although seedling recruitment was evident, it is unlikely that these late germinating seedlings (September) would survive until the next growing season. Studies by Shamsi and Whitehead (1974) revealed that summer-germinated loosestrife seedlings did not develop more than four to five pairs of leaves before the onset of winter and thus had a lower survival rate than spring-germinated seedlings. Nevertheless, Welling and Becker (1990) suggested that even where chemical treatment eliminated established plants and seedlings that subsequently emerge, the probability of exhausting an established seedbank is remote.

Resprouting shoots from mature loosestrife rootcrowns were also observed at 10 WAT. Resprouting was visually noted more frequently in areas treated with the low rate of triclopyr (0.75-percent solution). Statistically, the triclopyr treatments did not differ in their ability to reduce purple loosestrife populations; however, the observance of regrowth suggests that the low rate of triclopyr may be insufficient to completely eliminate mature, underground rootcrowns. Inadequate canopy penetration or coverage of chemical spray during application may also result in poor control and/or regrowth.

Table 1
Mean Percent Cover of All Plant Species Present in the Weaver Bottoms Test Area Prior to Chemical Application

Scientific Name[1]	Common Name	Mean Percent Cover
	Dicots	
Lythrum salicaria	Purple loosestrife	51.26
Polygonum sp.	Smartweed	0.46
Indogofera sp.	Indigo	0.46
Rumex sp.	Dock	0.21
Ceratophyllum demersum	Coontail	0.21
Nymphaea odorata	White water lily	0.06
Asclepias incarnata	Marsh milkweed	0.03
Myriophyllum exalbescens	Watermilfoil	0.03
	Monocots	
Sagittaria latifolia	Broad-leaved arrowhead	11.89
Phalaris arundinacea	Reed canary grass	10.37
Sparganium eurycarpum	Giant bur-reed	3.87
Lemna sp.	Duckweed	2.27
Eleocharis sp.	Spike rush	1.74
Typha latifolia	Broad-leaved cattail	1.14
Scirpus fluviatilis	River bulrush	0.88
Carex sp.	Sedge	0.66
Phragmites sp.	Reed grass	0.49
Open Space (no plants)		27.63

[1] Species identified to generic level because the absence of flowering structures or other identifying features required for proper identification.

During the spring and summer of 1993, record high water inundated much of the upper Mississippi River Basin. Persistent weather patterns caused unusually excessive rains in June and July that, together with a wetter-than-normal spring, produced severe flooding throughout a nine-State region of the upper Midwest, including the study site. The nearest National Weather Service weather station located in Minneapolis, MN, recorded greater than 150 percent of the normal (based on a 30-year average from 1961-90) precipitation for the months of June and July and a 121-percent above normal average for the 7-month period of January through June (Wahl, Vining, and Wiche 1993). As a result, water levels in Pool 5 at Weaver Bottoms averaged 4.3 ft

Table 2
Percent Purple Loosestrife Canopy Cover (± SE) as Measured by Line Intercept Techniques Following Application of Garlon 3A

	Percent Cover		
Treatment	Pretreatment (6/29/92)	10 WAT (9/9/92)	2-Year Posttreatment (6/6/94)
1.0% Garlon 3A	51.51 (5.37)a	2.61 (0.89)b	0.28 (0.24)b
0.75% Garlon 3A	55.77 (7.51)a	9.11 (4.60)b	0.12 (0.12)b
Untreated Control	71.16 (2.20)a	91.47 (3.28)a	20.16 (5.95)a
LSD (0.05)	NS	13.32	18.61

Note: Garlon 3A = triethylamine formulation of triclopyr; Ortho X-77 surfactant added at 0.25% v:v.
Within columns, means followed by different letters are significantly different (LSD test, $P \leq 0.05$); WAT = Weeks after treatment.
NS = Not significant.

above normal from June through September, hindering 1-year posttreatment data collection.

The volume and duration of floodwaters had a significant impact on all of the vegetation at the test site. Two years after the initial herbicide treatment, purple loosestrife populations in all transects had substantially decreased (Table 2). Triclopyr-treated transects were nearly void (<1 percent) of purple loosestrife, whereas untreated areas showed a 72-percent decline in purple loosestrife cover compared with pretreatment population levels. Although flooding was not intended as part of this study, 2-year posttreatment data showed that areas treated with triclopyr followed by long-term submergence resulted in elimination of purple loosestrife. As with the 10-week post-treatment data, there were no significant differences between triclopyr treatment rates. It is interesting to note that despite the magnitude and duration of the 1993 flood conditions, purple loosestrife was reduced but not eliminated from untreated areas. Several researchers have reported that once purple loosestrife becomes established in an area, flooding alone has little effect on seedling and mature plant survival (Haworth-Brockman, Murkin, and Clay 1993; Mal et al. 1992; and Thompson, Stucky, and Thompson 1987). Moreover, flooding may also alter community composition in a wetland and threaten desirable and endemic species as well. In areas where water manipulation is practiced and feasible (managed wildlife impoundments), herbicide treatment followed by controlled flooding should be evaluated as a means for improved purple loosestrife control.

Because triclopyr is selective for control of dicots, changes within the monocot/dicot plant community were determined (Figure 2). Ten weeks after chemical treatment, percent cover of all dicots species significantly decreased compared with untreated areas ($P = 0.0012$) indicating triclopyr efficacy. The

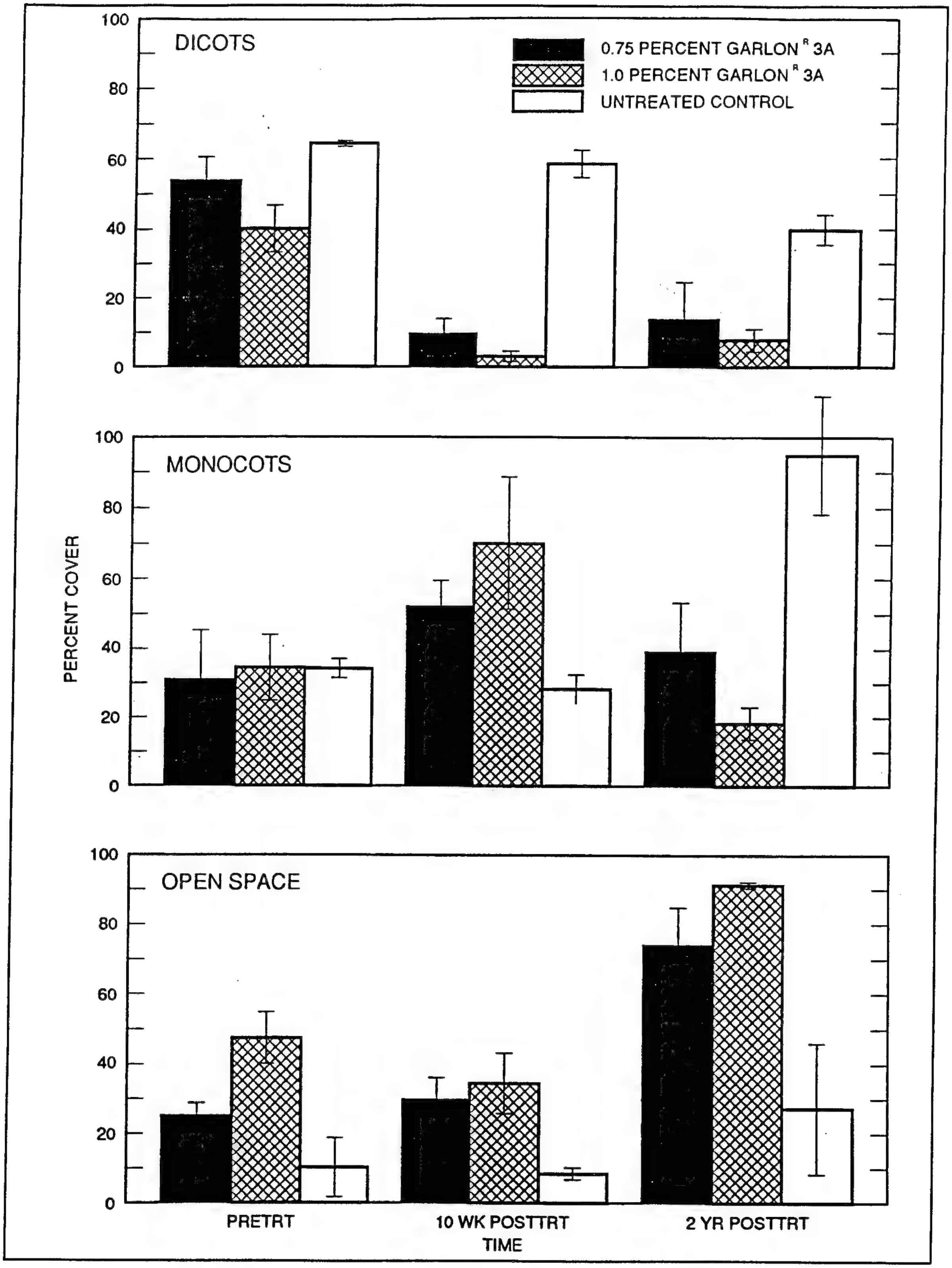

Figure 2. Percent cover (± SE) of monocots, dicots, and open space (no vegetation) before and after application of Garlon 3A. Data are means of cover values collected via quadrat sampling techniques along permanently marked transects in the area of treatment. Treatments were applied on June 30,1992

decrease in dicots corresponded to a significant increase in open space (no plants) (P = 0.0301). Although there was no statistical difference among treatments, monocots in the triclopyr-treated areas did show an increase 10 WAT. The most dominant monocot species that occurred in triclopyr-treated areas included the following (in decreasing order of percent cover): duckweed, broad-leaved cattail, rice cutgrass (*Leersia oryzoides*), reed canary grass, and giant bur-reed. As expected, there was little change in the plant community structure of untreated areas.

By the time of the next data collection, 2-years posttreatment, only monocots showed a significant difference among treatments (P = 0.0497). Untreated areas had significantly more monocots than triclopyr-treated areas. Monocot species in the untreated areas, (specifically broad-leaved arrowhead, reed canary grass, river bulrush, broad-leaved cattail, giant bur-reed, and sedges) increased by approximately 70 percent from the 10-week evaluation in 1992 to 1994. All treatments increased in the percent of nonvegetated area (open space) from the 10 WAT evaluation. Because of variability in the data however, there were no significant differences among treatments. Percent cover of dicot species increased slightly from the 10-week to the 2-year posttreatment evaluation for triclopyr-treated areas, and showed a decrease (32 percent) in untreated areas. Despite significant decreases in percent cover of purple loosestrife (as previously discussed in Table 2), the most frequently encountered dicot species in all sampled quadrats was purple loosestrife. There were no statistical differences in percent cover of dicots between treatments 2 years after chemical application.

In summary, the triethylamine salt formulation of triclopyr, Garlon 3A, was effective at controlling purple loosestrife populations at the Weaver Bottoms test site. Although there were no significant differences in percent cover of purple loosestrife between the two treatment rates evaluated, regrowth from rootcrowns was more evident in areas treated with a 0.75-percent solution of Garlon 3A than in areas treated with a 1.0-percent solution of Garlon 3A. Surviving rootcrowns are neither desirable nor acceptable from the standpoint of successful management of purple loosestrife. Rootcrowns are major photosynthate storage organs for perennial plants and would likely survive and resprout the next growing season, thus providing a source of reinfestation. Seedling recruitment was observed in all triclopyr-treated areas 10 WAT; however, late germinating seedlings have a low survivability and thus would not pose a threat of immediate reinvasion. Seedling recruitment during the following growing season (1-year posttreatment) was not investigated because of high flood waters that inundated the test site from June-September of 1993. Results from this triclopyr demonstration are similar to those reported by other researchers. Gabor et al. (1993) found that a 1.5-percent solution of Garlon 3A effectively controlled adult purple loosestrife plants and had a neutral or positive effect on the abundance of native plant species in an Ontario wetland. Seedling recruitment was also observed in this study. Purple loosestrife plots in Washington treated with 0.5-, 1.0-, and 2.0-percent solutions of Garlon 3A

showed a 99-percent reduction in loosestrife 3 months after treatment.[1] Moreover, the highest treatment rate continued to show an 87-percent reduction in loosestrife 1 year after treatment.

[1] Personal Communication, 1992, Vanelle Carrithers, DowElanco.

4 Conclusions and Recommendations

Conclusions

The following conclusions can be made based on the results of this study:

a. The triethylamine salt formulation of triclopyr (Garlon 3A) is an effective chemical control tactic for reducing purple loosestrife cover. Although the data showed no significant differences between Garlon 3A rates of 0.75 and 1.0 percent, areas treated with the higher rate had less regrowth.

b. Although triclopyr effectively controlled adult purple loosestrife plants, seedling recruitment can be expected.

c. Unexpected long-term flooding in 1993 greatly reduced but did not eliminate purple loosestrife populations in untreated Control plots. This flooding event somewhat confounded the evaluation of restoring purple loosestrife-infested wetland communities using triclopyr alone.

Recommendations

Based on results of this study the following recommendations are made:

a. A 1-percent application of Garlon 3A (triclopyr amine), tanked mixed with an approved aquatic surfactant (e.g., X-77) at 0.25 percent v:v is advised to selectively control mature purple loosestrife plants. Thorough coverage (spray-to-wet) of the plant with the tank mix material during early flowering stage should provide optimum control. Spot treatment of resprouted stems and seedlings may be required to achieve complete control.

b. Continuing to monitor the Weaver Bottoms test site for long-term changes to the vegetative community is recommended. It would be of interest from a management standpoint to continue to document

vegetative changes following both the triclopyr treatment and the 1993 flooding event.

c. Herbicide treatments followed by flooding events should be evaluated as an integrated management tool for improving control of purple loosestrife.

d. It is known that timing of application is important to maximize chemical efficacy. Recent studies documenting phenological events of other noxious plant species (Eurasian watermilfoil, water hyacinth, and cattail) have shown that coordinating management strategies with weak points in the life cycle of these target plants increases the efficacy of control efforts. Little is known concerning the coordination of purple loosestrife phenology with control tactics. Knowledge of a plants' physical state and of visible indicators that define susceptible points in the life cycle would benefit managers in identifying the proper timing of application of control strategies.

e. Further testing with triclopyr and other aquatic herbicides and herbicide combinations should be evaluated for management of purple loosestrife. Multiple applications to reduce seedling recruitment should be examined.

f. The efficacy of planting a cover crop following herbicide treatments to retard the re-establishment of purple loosestrife should be investigated.

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Appendix A Toxicological Information for Glyphosate, 2,4-D, and Triclopyr[1]

Table A1
Summary of Toxicological Properties of Glyphosate[1]

Test[2]	Species	Glyphosate Concentration[3]
96-hr LC_{50}	Trout	Technical (acid): 86 mg/L
	Bluegill	120 mg/L
	Daphnia magna	780 mg/L
	Carp	Rodeo Formulation: >10,000 mg/L
	Trout	>1,000 mg/L
	Daphnia magna	930 mg/L
	Bluegill	1,000 mg/L
Acute Oral LD_{50}	Quail	Technical (acid): >3,850 mg/kg
	Rat	5,600 mg/kg
	Rat	Rodeo Formulation: >5,000 mg/kg
8-day Dietary LC_{50}	Quail	Technical (acid): >4,640 ppm
	Duck	>4,640 ppm
48-hr LD_{50}	Honeybee	Technical (acid): >100 μg/bee
Acute Dermal LD_{50}	Rabbit	Technical (acid): >5,000 mg/kg Rodeo Formulation: >5,000 mg/kg
Chronic 2-year Feeding Study	Rat, dog	300 ppm; no adverse effect
Mutagenicity	Mouse	Negative
26-month Feeding Study	Rat	NOEL = 31 mg/kg/day; no oncogenic effects, highest dose tested

[1] From WSSA (1989) and Atkinson (1985).
[2] LC_{50} = lethal concentration that kills 50 percent of the individuals, plant or animal. LD_{50} = lethal dose, given as milligram per kilogram of body weight, which kills 50 percent of a group of test organisms.
[3] NOEL = no observable effect level.

[1] References cited in this appendix are located at the end of the main text.

Table A2
Summary of Toxicological Properties of 2,4-D[1]

Test[2]	Species	2,4-D Concentration[3]
96-hr LC_{50}	Trout	Technical acid: 35-56 ppm 2,4-D DMA: >100 ppm
	Bluegill	2,4-D DMA: 123-230 ppm
	Fathead Minnow	2,4-D DMA: 245-458 ppm
		2,4-D DMA:
	Gammarus fasciatus	2,4-D DMA: >100 ppm 2,4-D IOE: 1.9-3.0 ppm
Acute Oral LD_{50}	Mallard	1,000 mg/kg
	Pheasant	472 mg/kg
5-day Dietary LC_{50}	Quail	5,000 ppm
	Mallard	5,000 ppm
	Pheasant	5,000 ppm
Chronic 2-year	Rat (diet = 1,250 ppm)	No effect
Feeding Study	Dog (diet = 500 ppm)	No effect

[1] From WSSA (1989), Westerdahl and Getsinger (1988), and Fletcher and Kirkwood (1982).
[2] LC_{50} = lethal concentration that kills 50 percent of the individuals, plant or animal. LD_{50} = lethal dose, given as milligram per kilogram of body weight, which kills 50 percent of a group of test organisms.
[3] 2,4-D Technical acid = 100-percent acid equivalent (a.e.); 2,4-D; IOE = isooctyl ester formulation (67-percent a.e.); 2,4-D DMA = dimethylamine salt formulation (49-percent a.e.)

Table A3
Summary of Toxicological Properties of Triclopyr[1]

Test[2]	Species	Triclopyr Concentration	
94-hr LC_{50}	Trout	117 ppm	552 ppm
	Bluegill	148 ppm	891 ppm
	Shrimp	--	895 ppm
	Crab	--	>1,000 ppm
48-hr LC_{50}	Oyster	--	>56 ppm
Acute Oral LD_{50}	Rat (female)	713 mg/kg	2,140 mg/kg
	Rat (male)	713 mg/kg	2,830 mg/kg
	Rabbit	550 mg/kg	--
	Guinea Pig	310 mg/kg	--
Acute LD_{50}	Mallard	1,698 mg/kg	3,176 mg/kg
8-day Dietary LC_{50}	Mallard	>5,000 ppm	>10,000 ppm
	Bobwhite quail	2,935 ppm	11,622 ppm
90-day Subacute Toxicity	Rat	No effect	30 mg/kg/day
Teratology	Rabbit	Not Teratogenic	100 mg/kg/day

[1] From WSSA (1989).
[2] LC_{50} = lethal concentration that kills 50 percent of the individuals, plant or animal. LD_{50} = lethal dose, given as milligram per kilogram of body weight, which kills 50 percent of a group of test organisms.
[3] Garlon 3A = triethylamine salt formulation of triclopyr; used in aquatic environments.

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13. ABSTRACT (*Maximum 200 words*)

Purple loosestrife (*Lythrum salicaria*) is an exotic wetland weed that rapidly displaces native vegetation resulting in monotypic stands that reduce vegetative diversity and degrade wildlife habitat. Use of nonchemical management techniques, e.g., flooding, draining, cutting, and burning, is inherently nonselective and seldom results in long-term control of purple loosestrife infestations. Some herbicides offer a selective technique for reducing purple loosestrife levels, eradicating pioneer colonies of the plant, and restoring native wetland communities.

The objectives of this study were to evaluate effectiveness of the herbicide triclopyr on purple loosestrife, and to monitor changes in the plant community following triclopyr treatment. Stands of purple loosestrife, located in the Upper Mississippi National Wildlife and Fish Refuge, MN, were treated with an amine formulation of triclopyr (Garlon 3A) on 30 June 1992. Application rates were 0.75 and 1.0 percent Garlon 3A. Percent cover of purple loosestrife and associated plant species were monitored using line-intercept techniques pretreatment, and at 10 weeks and 2 years posttreatment. Results showed that Garlon 3A is an effective product for significantly reducing purple loosestrife cover; however, seedling recruitment can be expected. Although data showed no significant differences between rates tested, areas treated with the higher rate had less regrowth. This research resulted in a chemical technique for controlling purple loosestrife in wetland communities that includes minimizing damage to nontarget plants, particularly monocots, while offering a potential for restoring a diverse plant community.

14. SUBJECT TERMS

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